

Quantification of Changes in Relaxation Rates R_2^* and R_2 in Activated Brain Tissue

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PURPOSE:

Using spin-echo and gradient-echo echo-planar imaging (EPI), we observe a TE-dependent signal enhancement in the primary motor cortex during finger movement. From this observed dependence, we quantify the change in intrinsic tissue relaxation rates R_2^* and R_2 that occur during cerebral tissue activation.

INTRODUCTION:

Using gradient-echo imaging techniques, signal enhancement has been observed in the motor cortex (1-4) and visual cortex (1,2,5) during task activation and photic stimulation, respectively. It is hypothesized that the observed signal enhancement is due primarily to a local increase in blood oxygenation causing a decrease in paramagnetic deoxyhemoglobin concentration in the microvasculature during cerebral tissue activation (3). A spin-echo is attenuated by irreversible dephasing of spins diffusing through field inhomogeneities and a gradient-echo is additionally attenuated by dephasing due to static field inhomogeneities, independent of diffusion. According to the model, a longer TE should enhance the sensitivity to any change in concentration in deoxyhemoglobin by increasing the intravoxel dephasing effect. We provide evidence in support of this model by observing such a TE-dependence of the activation-induced signal enhancement.

METHOD:

Imaging was performed on a standard clinical GE 1.5-T Signa using a 30.5 cm i.d. three-axis local gradient coil. Blipped, single-shot, gradient-echo and spin-echo EPI pulse sequences were employed. Data acquisition time was 40 ms to acquire a 64 x 64 image. The FOV was 24 cm. Slice thickness was 20 mm. TE values ranged from 10ms to 160ms in the gradient-echo sequence and from 30ms to 200ms in the spin-echo sequence. For each TE value used, a series of 100 sequential images of the same plane in the brain was obtained using an inter-scan delay or TR of 2s. Twice during each time-course series the 5 subjects were instructed to move their fingers in a repetitive and sequential manner.

One ROI, (11.25mm x 11.25mm x 20mm), in the motor cortex was plotted in time over a range of TE values for both sequences. The slice location and thickness was chosen so that the ROI used for the time-course plots contained no inactive tissue along the width of the plane, thus avoiding partial volume averaging and consequent underestimation of relaxation rate changes. Using temporally averaged values from the time-course plots during activation, S_a , and during rest, S_o , ΔR_2^* and ΔR_2 were quantified by calculation of the slopes of the linear fits to $-\ln(S_a/S_o)$ vs TE, understanding that (6):

$$\text{Gradient-Echo: } \Delta R_2^* = -\ln(S_a/S_o)/TE = \Delta(1/T_2^*)$$

$$\text{Spin-Echo: } \Delta R_2 = -\ln(S_a/S_o)TE = \Delta(1/T_2)$$

RESULTS:

Gradient-echo and spin-echo time-course plots from the motor cortex at three different TE values are shown in Figs. 1 and 2, demonstrating TE-related signal enhancement. The gradient-echo sequence shows significantly more task activation-related signal enhancement at corresponding TE values. Values of $\Delta R_2^* = -0.68 \text{ s}^{-1}$ and $\Delta R_2 = -0.15 \text{ s}^{-1}$ were obtained from the slopes of Fig. 3., which is a plot of $-\ln(S_a/S_o)$ vs TE for the spin-echo and gradient-echo EPI sequences.

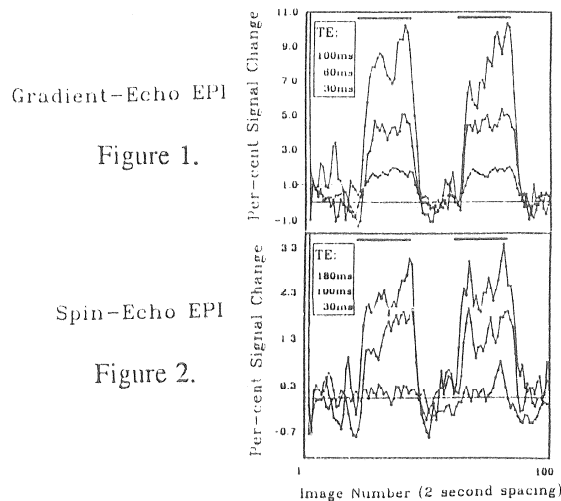


Figure 1.

Figure 2.

CONCLUSIONS:

Signal enhancement in the human brain during task activation is shown to be dependent upon the pulse sequence and TE used. The observed intrinsic signal enhancement using the spin-echo sequence is a finding which suggests that significant diffusion of spins through the microscopic field gradients is taking place. The fact that gradient-echo sequences show a greater signal change at corresponding TE values indicates that, on the microvessel scale, static frequency offsets dominate over diffusion through microscopic field gradients to cause deoxyhemoglobin-related intravoxel dephasing.

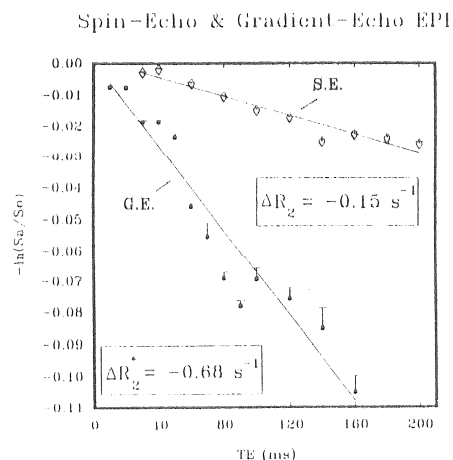


Figure 3.

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